

after a period of two months; and for pocket-chronometers, 1'57 sec. after a trial of six weeks; and the average differences between the maximum and minimum rates proved to be, for box-chronometers, 3'23 sec., after a two months' trial; and for pocket-chronometers, 6'22 sec. and 5'75 after six weeks and one month's trials. These figures show certainly that there is enough to do yet in raising the industry to the high degree of perfection which is desirable, but the steady progress during the last ten years is remarkably seen in a table showing the increase of precision of the Swiss chronometers in every direction. Thus the average diurnal variation, which was as high as 1'27 sec. at the competition of 1864, regularly decreases to 0'46 in 1875; the average variations of rate produced by changes of position, being 8'21 sec. ten years ago, is now but 1'97; and the defective compensation for temperature rapidly decreases from 0'48 sec. for each degree to 0'16, and now it is but 0'13. Besides, the report states, some of the best chronometers reach as high a degree of perfection as to make them comparable with astronomical clocks. Thus the box-chronometer which received the first prize is a true phenomenon of its kind. Its mean diurnal variation is as low as 0'08 sec., i.e., that of good astronomical clocks; its mean weekly rate changed after a two months' trial only by 0'57 sec.; the difference between the maximum and minimum rates is but 0'94 sec., and the imperfect compensation for temperature is 0'04 sec. for each degree; finally, its characteristic number, calculated by the Greenwich method, reaches but 8'90 sec. The two best pocket-chronometers realise perhaps a yet greater success, their average diurnal variations being respectively but 0'13 and 0'17 sec.

#### THE BRITISH ASSOCIATION

THE two *soirées* that were held in the Guildhall, the first on the evening of Thursday, the 16th instant, and the second on Tuesday, the 21st, were very fully attended.

At the second *conversazione* several objects of scientific interest were exhibited. At the centre table Prof. Herbert McLeod showed his beautiful cycloscope, an instrument which formed the subject of a paper read by Prof. McLeod before Section G on Wednesday week. Mr. Silvanus P. Thompson, of University College, Bristol, showed his apparatus for exhibiting certain optical illusions, upon which a paper was read by him in Section A. Prof. Osborne Reynolds showed the apparatus by which his paper upon the rate of progression of groups of waves was illustrated; and Mr. J. W. Swan exhibited a modification of the Sprengel pump.

In the picture gallery Dr. Graham Bell had his articulating telephones at work.

There was great competition for the tickets for the excursions for both Saturday and Thursday. The excursion to Lee Moor under the guidance of Mr. Spence Bate, F.R.S., was originally limited to 100, but there were more than 300 applications for tickets, and extra waggonettes had to be put on. The party, after having visited the China Clay Works of Messrs. Martin, the largest establishment of its kind in the world, divided into three parties: the first walked across the Moor to Sheepston, to examine some prehistoric remains recently discovered by Mr. Spence Bate. Another party under the charge of Mr. Martin took a walk to Shell top and Pen Beacon, from which fine views may be had; and a third detachment remained in the grounds of Mr. Martin, which are unique in their way, from the intricacy of their laying out.

The popular excursion of the day was, however, that up the Hamoaze and Tamar, to H.M.S. *Cambridge*, under Great Albert Bridge at Saltash, into the Sound, and visiting the Breakwater and Eddystone Lighthouse.

The Admiral of the Port placed three Government steamers at the disposal of the Association, and there was tremendous crowding to get on to the boats. Upon reaching H.M.'s gunnery ship *Cambridge*, the gunnery and torpedo practice began, and some splendid feats of firing at long ranges were exhibited.

On the same day there was a dredging excursion under the superintendence of Mr. Gwyn Jeffreys and Mr. Header.

While these excursions were going on a select party was, at the invitation of the Mayor and Corporation of Exeter, visiting that ancient city. At the luncheon, the toast of "The British Association," was proposed by Sir Stafford Northcote, Chancellor of the Exchequer, and responded to by Mr. Spottiswoode, F.R.S., the President-elect.

The excursions on Thursday last were first to Liskeard, the Cheesewring, and the Caradons, at the invitation of the Mayor of Liskeard. The second excursion was by way of the Tamar to Morwellham to the celebrated Devon Consols Copper Mines, taking on its way the fine old mediæval mansion of Cotehele, which was thrown open to the members by the Earl of Mount Edgcumbe, to whom it belongs. The last of Thursday's excursions was to Totnes, Torquay, and Brixham, and like the Exeter excursion, was only by special invitation. It was divided into four sub-excursions (*a*), Archaeological, visiting Totnes and Betry Pomeroy Castles; (*b*), Mechanical, visiting the Experimental Works of Mr. Froude, F.R.S.; and (*c* and *d*), Antiquarian and Geological, the first to Kent's Cavern, under the guidance of Mr. Vivian, and the second to Brixham, with Mr. Pengelly, F.R.S.

The Plymouth meeting of the British Association for 1877 has been decidedly a quiet one; its attendance as a whole has been below the average, and its funds are proportionately low; but it has done good work, and it has been marked by several papers of great scientific interest. The discovery by Prof. J. C. Adams of the original papers of Newton respecting the rotation of the apse of the moon, the exhibition of the articulating telephone of Dr. Graham Bell and the very valuable suggestions contained in the address of Prof. Carey Foster, must all help to mark the Plymouth meeting in the annals of the Association as a valuable one, notwithstanding its failure in points of attendance and pecuniary position.

The following are some of the figures connected with the recent meeting:—

Number of tickets issued to Old Life Members	... 161
" "	New " 19
" "	Old Annual Subscribers 238
" "	New " 58
" "	Associates 447
" "	Ladies 283
There were also present, of Foreign Members	... 11
Making a total of	... 1,217

The total receipts from the sale of tickets amounted to 1,267*l.*

#### REPORTS.

Prof. O. Reynolds presented the *Report of the Committee appointed to consider what Effect Reversing the Screw had on the Steering of a Steamer under Full Way*.—Since the last meeting of the Association the Committee had carried out further experiments, and the results now obtained show that the larger the ship the more important the effect of reversing the screw became. In answer to the request of the Committee, the Admiralty had made a trial with H.M.S. *Speedy*, but the conditions under which it was conducted precluded the possibility of more light being thrown on the subject. The greatest speed was five knots, and the effect of the rudder with the screw reversed was so small that the vessel in most instances turned her forward end into the wind. The Admiralty had been urged to have experiments made with larger and more powerful ships, but as yet had not assented.

The Committee forwarded copies of their last year's report to the Admiralty, the Board of Trade, the Trinity House, and other corporations, but no intimation had been received as to any action being taken upon it. The report was discussed at the conference of the Association for the Reform and Codification of the Law of Nations last year at Bremen, where a resolution was agreed to declaring that the existing international rules for preventing collisions at sea were not satisfactory, and it was desirable the governments of maritime states should take counsel together with a view to amend the rules and adapt them more carefully to the novel exigencies of steam navigation. This showed that the subject had already attracted considerable attention, and it was important to notice that the conclusions of the Committee had not yet in the smallest degree been controverted. Numerous collisions had happened during the year, which, to judge from the law reports, might in many instances have been avoided had the effect of reversing the screw been known and acted upon; but it did not appear as if a consideration of this had influenced any of the judgments given. The collisions had for the most part been with small ships, and so had not come much into notice. The loss of the *Dakota*, however, was a disaster of the first magnitude, and would unquestionably cause the subject to be considered by the authorities.

*Report of the Committee for commencing Secular Experiments on the Elasticity of Wires.*—The Committee have been chiefly occupied with preliminary arrangements and preliminary experiments.

A room has been fixed upon in the tower of the University buildings in Glasgow for suspending wires for the secular experiments. In this room there is an available height of sixty feet. A tube of cast-iron, within which the wires are to be hung, is at present being erected, and will be ready in two or three weeks. The tube is to be 60 feet high and  $9 \times 4\frac{1}{2}$  inches in cross section.

Wires of gold, platinum, and palladium have been supplied by Messrs. Johnson and Matthey, and with these it is proposed to commence the secular experiments. These wires have been specially drawn for the Committee. Each of them weighs one grain per foot.

A cathetometer suitable for making observations on the wires after they are hung up in their place has been designed and is being constructed by Mr. James White, instrument-maker, Glasgow. Preliminary experiments have been undertaken for the purpose of determining Young's modulus, and the breaking weight of the gold, platinum, and palladium wires.

Some experiments have also been undertaken in connection with the subject under investigation as to the effect of continued application of force on the breaking-weight of steel wire and soft iron wire, and results of importance have been obtained. These experiments are still being carried on, and numerical results will be given in a future report. It is found that when a weight nearly as great as the breaking-weight is kept for a long time—several days, for instance—and applied to pull out a soft iron wire, the effect is to increase largely the strength of the wire. It is often increased by as much as 6 or 7 per cent.

*Report of the Committee on Luminous Meteors*, by J. Glaisher.—The Committee have to record a year of very active research and of diligent and successful observations of shooting stars, fire-balls, and aérolites since the last report. The toilsome work of mapping and projecting star showers, and comparing and arranging the radiant point in lists, has occupied so much attention that they have been obliged to postpone till next year the work of furnishing observers with a *résumé* of the known star showers. The autumn and winter months were marked by numerous large fire-balls observed in England and abroad, some of which are of very special interest. Two, if not more, aérolites have fallen in America, and one at Constantine, in Algeria. Besides the magnificent meteor seen in the United States on December 21 last, from which one of these aérolites was projected, an equally splendid aérolite passed over Cape Colony on March 16 last with loud explosions, but no aérolites are known to have fallen from it in its flight. Much of the attention of the Committee has been engaged in the continued examination and comparison of star showers, and valuable work has been performed by Mr. W. F. Denning. There have been no marked star showers for one or two years, but some examples of frequency on certain nights have occurred. The August shower of 1876 and of the present month have both been below the average. The work of the Committee has,

as in former years, been chiefly performed by Prof. A. S. Herschel.

*The Report of the Committee appointed to consider the Ordnance Datum Level.*—After detailing the various causes which they found had led to the uncertainties referred to in the communications made in 1875, the Committee came to the following conclusions:—1st, That of the two tide gauges at Liverpool, now purporting to refer to the old dock sill, the zero of that fixed at the south-east corner of the Canning dock was about 5·64 inches above that on the river face of the Canning Island, Liverpool. 2nd. That in order to reconcile the statement in the ordnance book of levelling, "that the datum level for Great Britain is 8-roths of an inch above the mean tidal level obtained from the records of the self-recording tide-gauge on the St. George's Pier, Liverpool," with the usual facts which the Committee have collected, it is necessary to bear in mind that the records of the self-acting gauge referred to were the observations of one month only of the year 1859, and that the mean tide of that period was 7·8 inches below the mean decade from 1864 to 1873. 3rd. That the difference of levels between the old dock sill and the ordnance datum, given in the ordnance book of levelling as 4·67 feet, is correct on the assumption that the zero of the gauge on the face of the Canning Island, and not that of the gauge in the Canning dock, be taken as the correct level of the old dock sill, and that, as stated in the ordnance book of levelling, the ordnance datum be taken at 8-roths of an inch above the mean tide level of the month of March, 1844, as ascertained by the ordnance department. 4th. That it is thus apparent that the ordnance is an entirely arbitrary level, and could not be again obtained from tidal observations. The committee had thought it advisable to take advantage of the present inquiry in order to obtain information as to some of the various local datum marks in use in the British Isles, and to endeavour to ascertain the difference of each relatively to the ordnance datum, which would thus be the means of comparison between them. In order to enable the Committee to carry out this work they begged to be re-appointed.

*Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals*, by W. N. Hartley, F.R.S.E.—In a paper read at the Glasgow meeting of the Association, Mr. Hartley described the method of determining the exact temperature at which the carbonic acid sometimes found inclosed in minerals becomes gaseous. This temperature is called by Prof. Andrews the critical point, and has been determined by him in the case of pure carbonic acid prepared artificially to be 30°92 C. Mr. Hartley gives a table showing the critical point of carbonic acid inclosed in various minerals in which certain variations from Dr. Andrews' number are apparent; these, however, may be accounted for when the critical point is below the normal point by the carbonic acid being mixed with some incondensable gas like nitrogen.

It seemed desirable to ascertain whether the presence of liquid carbonic acid in rocks was not of frequent occurrence, and whether the immense number of cavities dispersed through various minerals which are usually considered to contain water may not often contain liquid carbonic acid, or whether the occurrence of this body is characteristic of certain formations. A considerable number of minerals was examined, including sapphires, zircons, garnets, topazes, and sections of fluor spar. Incidentally the inquiry led to some very interesting results concerning the motion of the bubbles in fluid cavities when influenced by some source of heat, of which the following is a summary:—

1. The bubbles in certain fluid cavities approach a source of heat brought near them.
2. The bubbles in certain cavities recede from the source of heat.
3. That 5° C. rise of temperature suffices to cause the apparent attraction.
4. That a rise of  $\frac{1}{2}$ ° C. will in some cases cause the apparent repulsion.
5. That in certain cases a bubble which receded from the source of heat at ordinary temperatures approached it when raised to 60° C.; the source of heat always being from  $\frac{1}{2}$ ° C. to 5° warmer than the specimen.
6. That this could occur in cavities containing liquid carbonic acid as well as water, but that it made no difference whether the carbonic acid was raised above its critical point or not.

Mr. Hartley has also examined a remarkable vibration of minute bubbles in fluid cavities first noticed by Mr. Sorby. It was found that these bubbles approached a warm body

brought near them, and that they ceased moving, and clung for some time to the warmer side of a cavity. The conclusion arrived at for these phenomena is as follows:—It is impossible to imagine a body which is not gaining or losing heat, or at the same time gaining and losing heat; it is therefore impossible to imagine it as entirely throughout of a uniform temperature. It is evident, then, that an easily movable particle, which can be set in motion by exceedingly slight differences in temperature, will make the transference of heat from one point to another plainly visible. The minute bubbles in the cavities are such particles, and these vibratory motions afford ocular demonstration of the continual passage of heat through solid substances. A further continuation of the research was extended to the conditions under which solid particles exhibit the Brownian movement.

Concerning the presence of liquid carbonic acid in minerals, Mr. Hartley finds that it is not of common occurrence, but only occasionally met with. He also describes in his report the means of demonstrating in certain cavities the continuity of the gaseous and liquid states of matter as shown by Dr. Andrews in his well-known experiments. Regarding the proportion of gaseous and liquid carbonic acid to water in the cavities, some important generalisations have been arrived at.

Mr. Hartley gives reasons in the report which cause him to fix the temperature of formation of the mineral in the case of topaz somewhere above  $342^{\circ}$  C., the critical point of water. In certain other cases in which the cavities differ in the nature of their contents, the water, he thinks, must at the time of their formation have been in the liquid state. It is possible to determine within certain limits the temperature which a rock or mineral has endured if liquefied carbonic acid is found inclosed in it.

*Report on some Double Compounds of Nickel and Cobalt*, by J. M. Thomson.—On attempting to prepare the so-called conjugated sulphate of nickel, cobalt, and potassium mentioned by Vohl (*Ann. Chem. Pharm.*, lxv.), who assigns to it the formula  $\text{NiCoK}_4(\text{SO}_4)_4 \cdot 12\text{H}_2\text{O}$ , it was found that the several fractions deposited successively form a solution containing molecular quantities of the simple potassium-sulphates of the two metals, possessed different colours, and showed also the property of dichroism to a remarkable degree. The operation having been repeated several times with a like result, it was determined to examine whether any regular replacement of the two isomorphous metals took place. Quantities of the two salts were dissolved in a sufficient quantity of water, and the resulting solution evaporated gently over a water bath at a temperature of  $80^{\circ}$ , the crystals being allowed to deposit in successive fractions.

The crystals of the conjugated salts are oblique prisms, having a tendency to modification when allowed to grow to any great size. The first fractions have a greenish grey colour when seen in the mass, showing the preponderance in them of the nickel potassium sulphate over the corresponding cobalt salt; the latter fractions, however, gradually become more crimson in colour as the cobalt potassium sulphate preponderates over the nickel salt. Details of analyses are given in the report, showing the different quantities of nickel and cobalt contained in the several fractions.

It is shown that Vohl's formula may be correct for isomorphous metals having a considerable difference in their atomic weights, but fails when two metals, such as nickel and cobalt, having the same atomic weights, occur in the conjugated salts, as they give rise to replacements requiring a very high molecular formula to express their constitution.

The examination of the optical properties of the several fractions possesses some interest. It was observed that the colours shown through the different axes passed in a direct order down the spectrum. In the first fractions the more highly refractive rays of the cobalt spectrum mingle with the green of the nickel, whilst in the latter, the two rays are those adjacent to each other in the cobalt spectrum.

That these salts or fractions are not merely isomorphous mixtures is shown by the fact that large crystals taken for analysis exhibit throughout the same dichroism. If, then, the phenomenon of dichroism is dependent on molecular constitution, as seems probable, it follows that all bodies exhibiting dichroism must be definite chemical compounds, and therefore the molecular formulae of some of these must be far more complicated in their structure than is at present imagined.

*Abstract of the Thirteenth Report of the Committee for exploring Kent's Cavern, Devonshire*.—The Committee, in their Twelfth Report, read at Glasgow last year, brought up the history of their researches to the end of August, 1876. They have

now the pleasure of continuing that history to the end of July, 1877. During the intervening eleven months the work has been continued without interruption, on the same method and under the same daily superintendence as heretofore. The workmen named in the Twelfth Report are still employed on the exploration, and continue to give unqualified satisfaction.

On November 2, 1876, Mr. Busk, a member of the Committee, visited the cavern, accompanied by one of the superintendents, when he inspected that portion of the work which was then in progress, as well as the principal parts where the exploration has been completed.

The researches continue to attract large numbers of visitors, most of whom are admitted by the authorised guide, who, under well-defined and strictly-observed regulations, conducts them through such branches of the cavern as are of general and popular interest, but not to those in which the work is in actual progress, or has not been begun. The superintendents have also had the pleasure of accompanying a large number of visitors, including men of all professions and of various countries.

*The Bear's Den*.—The chamber termed the Bear's Den measures about sixty-seven feet in length, from north to south nearly, from eight to thirty-eight feet in width, and from eight to fifteen feet in height, the last dimension being measured from the bottom of the excavation. The limestone roof is extremely rugged, fretted, and water-worn.

Adjacent to its western wall is a vast boss of stalagmite, which the superintendents have preserved intact on account of the inscriptions which crowd it. One of these, "William Petre, 1571," is of considerable interest on two accounts: 1, the date is, so far as is at present known, the earliest in the cavern, and the only one belonging to the sixteenth century; 2, Its genuineness can scarcely be doubted, as it is known that at the period in question there was a William Petre, a native of South Devon, quite a young man, and a nephew of Thomas Ridgway, who then resided on the estate in which the cavern is situated, and of which he was the proprietor. Moreover, in a lately discovered lease, dated 1659, and conveying "closes, fields, or pieces of ground," mention is made of "one close called Kent's Hole," thus showing that the cavern was so well known about the middle of the seventeenth century as to render it probable that it was known also, at least, as early as towards the close of the sixteenth.

As the Rev. Mr. MacLineny broke ground in every part of the Bear's Den fifty years ago, its original condition can only be learned from the description of it which he has left, and which may be given in the following very condensed form:—

"The floor of the Bear's Den was studded with conical mounds of stalagmite supporting corresponding pendants from the roof. Fallen masses of limestone were strewn about, and some of them were incorporated in the crust. An irregular sheet of stalagmite, about a foot thick, overspread the floor, and was based on a shallow bed of indurated rubble containing tubes of stalactite collected in heaps in particular places, a great abundance of *album græcum*, an unusual proportion of bear's teeth, and an iron blade much corroded. Points of stalagmitic cones were observed to protrude upwards into the rubbly bed, and were found to rise from a lower sheet of stalagmite. The cones of this lower sheet were precisely under those of the upper, denoting that they were successively deposited from the same tubes above, but the lowermost set exceeded by double the thickness of the uppermost, and the depth of the stalagmite sheet was in the same proportion. The lower sheet extended over the entire area of the den, but the superincumbent bed of rubble, and its overlying thin sheet of stalagmite, 'thinned out' towards the sides. The removal of these partial beds displayed the entire surface of the lower sheet, which exhibited a most singular appearance. Over the whole area it was cracked into large slabs, resembling flags in a pavement. The upper sheet was not in the least fractured. The average thickness of the cracked sheet was about two feet. It possessed the hardness of rock, and but for its division into insulated flags it would have been almost impossible to pierce it."

"The first flag we turned over displayed a curious spectacle. Skulls and bones of bear, crowded together, adhered to its under surface. Flag after flag disclosed the same phenomenon; but in one place numerous skeletons lay heaped on each other; the entire vertebral column and its various other bones, even to the phalanges and claws, were discovered lying in their natural relation, in a state of preservation as if belonging to the same individual. The remains of bear prevailed here to the exclusion of all other animals. Some of the teeth were of the most dazzling

enamel, and the bones of their natural fresh colour. Others, on the contrary, were of a darkish brown; even the enamel was of a greenish tinge. Owing to the induration of their earthy envelope, or their incrustation by stalagmite, few were extracted entire. Two skulls were buried in the stalagmite as in mould, and were brought away in that state. In no case were the remains broken or gnawed by the jaws of carnivores. The long bones were generally found entire; and when observed broken, it was only mechanically from pressure. The bones were highly mineralised, heavy, brittle, and easy of fracture; and, when struck, rang like metallic substances."

The portions of the stalagmitic floor which Mr. MacEnery had failed to break up, chiefly adjacent to the walls and other confines of the Bear's Den, furnished the Committee with two good examples of the remarkable cracks of which he speaks. One of these was in the north-east corner, where a crack, about half-an-inch wide, extended from wall to wall, a distance of about twelve feet, passing quite through the stalagmite, which was nowhere less than two feet thick, but without faulting it in the slightest degree, or, so far as could be observed, in any way affecting the underlying deposit. Mr. MacEnery, however, states, though somewhat obscurely, that in some instances a derangement had taken place in the materials covered by the broken stalagmite. The second existing crack varies from 2·5 to 2·5 inches wide, and passes completely through the boss of stalagmite already mentioned, but without faulting it. No such cracks appear to be mentioned by Mr. MacEnery as occurring elsewhere, nor have the Committee met with anything of the kind in any other branch of the cavern.

The ground broken by Mr. MacEnery extended to a depth of from eight to twenty inches over almost the entire area of the Bear's Den. As was his wont, he left the excavated materials almost where he found them, and there were amongst them a large number of specimens which had been overlooked or neglected, including 1 tooth of horse, 1 of fox, 2 teeth of deer, 4 of hyena, 4 of mammoth, upwards of 200 of bear, very numerous bones, especially of the vertebral column and feet, a crowd of fragments of bone, numerous balls of coprolite, and a few bits of coarse pottery.

It cannot be doubted that such cracks as Mr. MacEnery describes must be a probable source of uncertainty respecting the position and relative chronology of some of the objects found in the underlying deposit, especially where this deposit shared in the disturbance.

In accordance with Mr. MacEnery's description and the foregoing considerations, the deposit the Committee had to excavate was the breccia, with a small amount of cave-earth lying on it here and there.

The excavation in the Bear's Den was limited, as in other branches of the cavern, to a depth of four feet below the bottom of the stalagmite, and the limestone floor was nowhere reached.

The "finds" in the Den were 216 in number, of which 12 were in the stalagmite; 101 in the first or uppermost foot-level, 47 in the second, 32 in the third, 23 in the fourth, or lowest, and 1 in a small recess. Omitting those found in the stalagmite and the recess, 32 of the "finds" were in cave-earth, 65 in a mixture of cave-earth and breccia, and 96 in the breccia; whilst the matrix of the remaining 10 must be regarded as uncertain. The colour and other characters of the specimens, however, indicate with tolerable certainty to what beds and eras they belong.

Besides a considerable number of bones and pieces of bone representing every part of the skeleton, the specimens included upwards of 620 teeth of bear, 24 of hyæna, 10 of horse, 7 of fox, 5 of mammoth, 4 of lion, and 1 of wolf (!), or of dog (?). There were also 20 "finds" of coprolite and 11 flints.

Amongst the bones the skull of a bear may be mentioned, which, to re-quote the language of Mr. MacEnery, was "buried in the stalagmite as in a mould, and was brought away in that state." Many of the specimens are of considerable interest, but perhaps none of them differ so much from those mentioned in previous Reports as to require detailed description.

None of the flints found in the Bear's Den are of so much interest as many of those exhumed in other branches of the cavern, and described in previous Reports.

A pillar of stalagmite was met with, in November, 1876, under the following peculiar circumstances:—It measured about fifty-one inches in basal circumference, and three feet in height. The base was nondescript outline, but everywhere above the pillar was rudely elliptical in horizontal section, and it measured thirty inches in girth at the height of one foot, where it was

least. When found, however, it was in two parts, having been divided along an almost horizontal plane, where it was thinnest. Each segment stood perfectly erect, but not one on the other; for though the bottom of the upper segment was on precisely the same level as the top of the lower, the upper portion had been moved westward to the extent of fifteen inches horizontally, and stood there on the breccia. It cannot be doubted that when the dislocation occurred the pillar had reached its full height, and the breccia had accumulated round it to the height of one foot; that is, it had reached the level of the plane of fracture. It is difficult to see how, by any possibility, the deposit could at that time have reached a greater height; and difficult also to understand how anything other than human hands could have shifted the upper segment and placed it so as to have preserved its erect position. On the other hand, it is just as difficult to see what motive man could have had for such a work. The whole, when found, was completely buried in the breccia, and the top of the upper segment was about a foot below the bottom of a thick remnant of the stalagmitic floor, which was intact and not cracked.

Rats, undoubtedly attracted by the candle grease dropped by the workmen, continue to present themselves wherever the work is in progress, irrespective of the distance from daylight.

*The Tortuous Gallery.*—As soon as the work in the Bear's Den was completed, the exploration of a narrow passage opening out of its southern end, and termed "The Tortuous Gallery," was begun. Its height varies from 1·5 to 6 feet, and its width from 1·5 to 4·5 feet. It proceeds in a southerly direction for about 23 feet, and then turns sharply towards the east. Ground had been broken, here and there, by the earlier explorers up to 11 feet from the Bear's Den. Everywhere farther in there was a continuous unbroken floor of stalagmite from 1·5 to 3·5 feet below the limestone roof. The underlying deposit was exclusively the breccia, or, so far as is known, the oldest the cavern contains. Its upper surface formed a continuous declivity, at a mean gradient of 1 in 2·5.

The "finds" met with in the Tortuous Gallery up to the end of August, 1877, were but fourteen in number, and the objects they contained were of but little importance. Six of them were in the first or uppermost foot-level—all near the entrance; two in the third; and six in the fourth—all at some distance from the entrance. They included, besides bones and bone chips, fourteen teeth of bear—some of them being in portions of jaws—and one tooth of horse. The latter was found on the surface, near the Bear's Den, with three bits of coarse, friable, black pottery.

On reviewing the work of the last eleven months, the superintendents cannot but express disappointment at not having found the very large number of choice specimens which Mr. MacEnery's glowing description had led them to expect in the Bear's Den. Nevertheless, the discoveries they have made not only justify his description, but show that in that branch of the cavern the osseous remains were almost entirely confined to the uppermost foot of the breccia, and mainly to its actual surface. So long as the lower levels remained untouched the belief that they were equally rich would naturally have prevailed; and it cannot be doubted that in disposing of this belief satisfactory work has been done.

No trace of *Machairodus latidens* has been met with since the Glasgow meeting.

*Fifth Report of the Committee for Assisting in the Exploration of the Victoria Cave*, drawn up by R. H. Tideman, secretary.—The work has been carried on almost continuously throughout the year until July 14, when the low state of the exploration fund rendered it advisable to give up working for the present. Prof. Busk has reported on the bones submitted to him. Out of 181 determined bones and teeth he reports of ox 46, deer 14, sheep or goat 16, hare 3-4, fox 5, bear 41, wolf 4, hyæna 30, rhinoceros 11, elephant 3, badger 7.

Of the ox one is *Bos primigenius*, the other probably *Bos longifrons*. Of the bears some are not unlike *Ursus spelaeus*; others are undoubtedly grisly bear. The hyænas are, as usual, individuals of various ages. Rhinoceros is represented by at least eleven well-marked specimens, all of which are clearly referable to *R. leptocephalus*.

Three or four fragments of elephants' teeth occur. Fourteen specimens of deer belong to red deer, but there is no clear indication of reindeer.

A small ruminant, probably goat, occurs; some of the bones appear to be rather recent. Badger, fox, a small wolf, hare,

abbit, several birds, and water-vole, complete the list of those which have been determined from the bones obtained in the year.

A great part of the work this year has been expended in lowering the levels in chambers A and D. An adit has also been cut from the further end of Chamber A to the end of Chamber D. This part was completely filled up to the roof with several beds of clay and stalagmite. These were all of earlier age than the hyæna bed, which was the great deposit of early pleistocene age. They were almost entirely free from animal life of any kind. The only specimens found were near the bottom of them, and in one spot, consisting of teeth of a small wolf. This, then, is by far the oldest inhabitant of the cave. The presence of wolf of course implies the presence of other animals.

The Committee is now working with a view to disclosing the old bed of the river which first formed the cave.

*Third Report of the Committee for Investigating the Circulation of Underground Waters in the New Red Sandstone and Permian Formations of England, and the Quantity and Character of the Water supplied to various Towns and Districts from those Formations*, drawn up by C. E. De Rance (secretary), with supplemental report by T. M. Reade.—No less than 10,000 square miles of England and Wales are occupied by the new red sandstone and permian formations, which absorb not less than ten inches of rainfall annually, and probably more where the overlying drift is pervious or absent, and the sandstone open and permeable.

The Rivers Pollution Commissioners classify waters in the order of their excellence, for general fitness for drinking and cooking, as follows:—

A. Wholesome.	1. Spring water.	Very palatable.
	2. Deep well water.	
B. Suspicious.	3. Upland surface water.	Moderately palatable.
	4. Stored rain water.	
C. Dangerous.	5. Surface water from cultivated land.	Palatable.
	6. River water to which sewerage gets access.	
	7. Shallow well water.	

The average amount of hardness of the water of the deep wells of the new red sandstone tabulated by the Rivers Pollution Commission being 17°9, and that of the springs no less than 18°8, the relation of hardness of water to the rate of mortality of the persons drinking it becomes a matter of great importance.

The Commissioners give three tables of statistics that bear directly upon this point:—

From Table I. it appears that in twenty-six towns, inhabited by 1,933,524 persons supplied with water, not exceeding 5° of hardness, the average death-rate was 29°1 per 1,000 per annum.

From Table II. we learn that in twenty-five towns inhabited by 2,041,383 persons drinking water of more than 5°, but not exceeding 10°, the average death-rate was 28°3 per 1,000.

Table III. gives sixty towns, with an aggregate population of 2,687,846, drinking water of more than 10° of hardness; the average death-rate was only 24°3.

Of the towns in Table I. none are supplied from the new red or permian formations.

In Table II. three are so supplied.

In Table III. ten are so supplied, from which it will be observed that the largest number of towns supplied with new red water are found in the table with the lowest death-rate and the hardest water.

The same result is obtained if we compare towns of corresponding populations and occupations supplied with soft waters from surface areas and those supplied with deep well water in the new red sandstone. Thus:—

		Per 1,000.
Manches'er, 351,189 inhabitants, average death-rate	...	32°0
Birmingham, 343,787	"	24°4
And again—		
Stirling, 14,279	"	26°1
Tranmere, 16,143	"	18°8

The averages are, of course, also dependent on many external causes. Thus, Greenock and Plymouth, both supplied with soft water, with an equal number of inhabitants have a death-rate respectively of 32°6 and 23°3 per 1,000, due to difference of density of population, Greenock only having one house for every

twenty-eight people. And again, Liverpool and Birkenhead, both supplied with moderately hard water in the one, an old and densely-populated town with a site saturated with what is injurious to health, the death-rate is 31 per 1,000, while Birkenhead, a new town on an open site with wide streets, has a death-rate of only 24 per thousand, though mainly inhabited by a poor and struggling class of persons.

Still it is worthy of note that the five inland manufacturing towns with the lowest death-rate are all supplied with hard water, and all from the new red sandstone.

	Population.	Mortality per 1,000 per annum.
Birmingham ...	343,787	24°4
Leicester ...	95,220	27°0
Nottingham ...	86,621	24°2
Stoke-on-Trent ...	130,985	27°9
Wolverhampton ...	68,291	25°9
Average ...	144,981	25°5

And again the average death-rate of twelve inland non-manufacturing towns supplied with soft water was 26°0 per 1,000, while that of twenty similar towns supplied with hard water was only 23°2.

When, however, the mortality of the districts, including the principal English watering places, is compared, there appears to be little variation in the death-rate, whether the population be supplied with soft, moderate, or hard water, so that it may be safely concluded that where sanitary conditions prevail with equal uniformity, the rate of mortality is practically uninfluenced by the degree of hardness of the water drunk, and the Rivers Pollution Commission are of opinion that soft and hard waters, if equally free from deleterious organic substances, are equally wholesome.

The Committee are of opinion that it is desirable that they should continue to inquire into areas where new red and permian waters might be obtained by means of deep wells. Looking to the national importance of utilising the underground waters of England, it is desirable that the sphere of this inquiry should be extended so as to include the oolites, which are often not made available for the supply of the population living upon them until the water is hopelessly polluted with sewage. The result of their labours, since the formation of the Committee, has been to prove that there is an available supply of water from the new red sandstone and permian of England of not less than a billion and a half of gallons of water, the quality of which is remarkably free from organic impurity, and the hardness of which does not in the least appear to affect the health of the population at present taking their supply from it. The death-rate of this area compares well with the best soft-water districts.

Mr. J. Mellard Reade, C.E., F.G.S., added a special report *On the South-West Lancashire Wells*, in which he analysed the information he had obtained for the Committee through the printed forms of inquiry, supplemented by further inquiries which had suggested themselves to him. For the purposes of comparison Mr. Reade selected three nuclei or centres, about which the most important systems of wells are grouped, viz., Liverpool, Birkenhead, and Widnes, and illustrated them by maps and vertical sections showing the relative water-levels reduced to a common datum.

The President thought it important to note the influence of heavy and long-continued rain in relation to absorption by rocks. When rain lasts only a short time, even if it were very heavy, only a little was absorbed; but if the rainfall were spread over a longer time, a larger proportion would sink into the rocks. M. Lebourg described the method adopted by the French engineers for representing the underground water-contours on maps, there being also lines showing the strike of the rocks; he recommended this method to the consideration of the Committee.

#### SECTION A.—MATHEMATICAL AND PHYSICAL.

*On the Relative Apparent Brightness of Objects in Binocular and Monocular Vision*, by Silvanus P. Thompson, B.Sc.—It is a common idea that objects appear brighter when seen with the two eyes than with one. There appear, however, to be exceptions to this statement. The following is a method of submitting the question to photometric measurement:—The comparison-

photometer employed consists of a cardboard screen, having an aperture divided into two equal portions. One half is covered with tissue paper and illuminated directly from behind. Behind the other half is set, at the polarising angle, a mirror of black glass. Light from a second lamp falls upon a screen of tissue paper, whose light is then reflected in the mirror. Thus the two halves of the aperture may be illuminated equally, but with light in one case wholly unpolarised ; in the other, wholly polarised. Let two Nicol prisms be now taken, having their principal sections placed parallel and perpendicular, respectively to the plane of polarisation of the mirror, and let one Nicol be placed in front of each eye. One eye only will receive the whole of the polarised light, while the unpolarised will be equally distributed, half to each eye. The total amount of light received upon the retinal surface will be the same from each half of the aperture ; but their apparent illuminations will be unequal, that of the polarised light appearing the greater. By comparing the distances at which the lamps must be placed, it appears that light is more powerful in producing an effect when concentrated upon one eye than when equally distributed to the two, though according to what law experiments are not yet sufficiently numerous or exact to determine ; but, on the other hand, the light so concentrated on one eye does not produce the sensation of twice as much illumination as the half of the light viewed by both eyes at once.

A paper by Mr. C. Meldrum was read *On the Diurnal Variations of the Barometer and Wind in Mauritius*. Mr. Meldrum remarked that in 1875, 1876, and 1877, the number of cyclones had been much below the average, and that there had not been any one great storm such as that which occurred in the periods 1860-63, and 1870-73. This, so far, confirms the hypothesis of a connection between the frequency of sunspots and the frequency of cyclones.

With regard to the rainfall the evidence in favour of a cycle corresponding with the sunspot cycle has much increased. Dr. Hunter, of Calcutta, has lately found for Madras a rainfall cycle identical with that which the author had previously found both for India and various other parts of the world. Mr. Meldrum has recently discussed the rainfalls of thirteen stations in the French colonies for various periods from 1832 to 1872, and obtained results nearly the same as those that had been found for 144 stations scattered over both hemispheres. Dr. Fritz, of Zurich, has shown that the severest hailstorms and the highest levels of the rivers occur on the years of maximum sunspot. In short there can, he thinks, be little doubt of an eleven-year rainfall cycle, and when its laws are known they will probably be of much practical use.

*Account of a Meteor which passed over Bhawnpoor, in India, in October, 1873*, by Major G. Noel Money.—In the beginning of October, 1873, I was staying for a few days at Bhawnpoor, capital of the independent state of the same name, which is situated along the left bank of the River Sutley, and north of the great sandy desert of Bikaneer.

Early one morning I was roused from my sleep by a sound exactly resembling that which would be produced by half-a-dozen express trains passing close to the house at the same moment. The room was as light as the brightest noonday. Before I had time to collect my thoughts, two violent explosions in rapid succession shook the whole house ; the doors and windows rattled for fully ten or fifteen seconds. Earthquakes being of not unusual occurrence in the north of India, particularly at that time of the year, I naturally concluded this was something of the kind, and hurried out of the house. As I did so the light faded, and I was surprised to find, as I reached the verandah, that it was still night, although the first streaks of dawn were visible in the east. The native servants were running out of their houses in the greatest alarm ; I asked what was the matter. "God knows ! the sky has fallen," was the reply.

After breakfast we heard that a shower of stones had fallen eighteen miles off to the north-east of Bhawnpoor, and later in the day some pieces were brought in. The largest was an irregular mass, as far as I can recollect about three feet long, and a foot thick ; still hot, blackened outside as if by the action of fire, of which it smelt strongly, of a dark grey colour inside, and very heavy. I have now a piece which I broke off this large mass ; although no bigger than a man's fist, it weighs nearly two pounds. The natives who brought these in said there were many more ; one, they declared, was as large as a bullock-cart, and so hot that they could not touch it.

It was afterwards ascertained that a second shower of pieces,

apparently the result of the second explosion, fell about thirty miles beyond the first. It is satisfactory to know that there was scarcely a possibility of deception as regarded these pieces ; there not being such a thing as a stone, rock, or pebble the size of a pea, within the radius of a hundred miles from Bhawnpoor, the soil being either pure alluvial deposit or the finest sand.

The accounts given by native eye-witnesses of this meteor were varied and unreliable, and one could only arrive at a satisfactory result by an exhaustive process of comparison, but I was fortunate enough to meet, the same day, a thoroughly trustworthy witness in the person of an European overseer who was superintending the works at a new palace, which was in course of erection for the Nawab at Bhawnpoor. This man had gone down to the works before daybreak to look after a brick-kiln, and being in an open space had an uninterrupted view of the meteor. He described it as a large ball of fire, as big as twenty moons, which passed, with a roaring sound, directly over his head in a north-easterly direction. It lit up the whole sky, the light being perfectly dazzling, and left behind it a flaming track of red, green, and yellow. Before passing out of sight two explosions in quick succession took place, at each of which a shower of sparks seemed to fall, but no alteration appeared in the size and shape of the meteor itself.

It has always been a subject of surprise to me that no attempt was made by Government to collect any information regarding this meteor. Had reports been called for from the various districts it would have been easy to ascertain where it was first and where last seen. Some estimate might then have been made as to its size and distance from the earth's surface.

To give some idea of its magnitude, I may mention that at Dera Ghazi Khan, seventy miles north of Bhawnpoor, it was seen and heard nearly as plainly as it was by us. At a place 200 miles north and a little west of Bhawnpoor, it was so brilliant that a native gentleman was, as he informed me, startled from his sleep by the sudden light, and ran out of his house thinking the next house must be on fire. He did not, however, hear any explosion.

Some soldiers of my regiment in Terar, in Afghanistan, 400 miles north of Bhawnpoor, told me that they had also seen it, and that it was so unusually large and brilliant that the mullahs (Mahomedan priests) were much exercised in mind about it, considering that it must forebode some calamity.

Very little notice was taken of the occurrence in the local papers, but this is to be accounted for by the fact that it passed over the most desert and thinly populated district in the whole of India. I believe, however, I am right in saying that it was also seen in Ajmere and Jypore, over 400 miles to the south-east of Bhawnpoor.

*On the Determination of Temperature Coefficients for Insulating Envelopes*, by T. T. P. Bruce Warren.—At the Exeter meeting of the British Association I read a paper on electrification, in which I endeavoured to show that the rate of variation in the insulation resistance of a core or cable under changes of temperature could be determined for any period of contact. A statement was made in that paper which has led to the belief that india-rubber has the same constant for correcting from one temperature to another, and for any period of contact.

Prof. Fleeming Jenkins, Mr. Latimer Clarke, and others have pointed out that this phenomenon is not met with in gutta percha, or any other insulator with which they are acquainted. This has led me to re-examine the matter, and to consider carefully the experimental data upon which the paper was founded.

The method of representing graphically the decrease of resistance due to increase of temperature corresponding to one minute's electrification, can be followed out for two, three, or any number of minutes. In this way a series of logarithmic curves are obtained for any required duration of contact ; these curves are generated by a constant which must first be ascertained by experiment for changes of temperature at the end of one, two, three, &c., minutes.

This was omitted in the previous paper, or at least not dealt with as the importance of such a subject required.

The phenomenon of electrification, from what has just been pointed out, must appear to every electrician to have received additional importance, so as no longer to be regarded as an unintelligible or inapplicable fact. One very important consequence of its being reducible to an intelligible variation is that we can now calculate not only the changes in the resistance of an insulator due to variation of temperature, but we can ascertain with the same precision any required change due to prolonged contact,

at any required temperature. The resistances at different temperatures under different durations of contact will, when tabulated, represent a series of logarithms, the base of each system being the ratio between the resistances for the same differences of temperature, but corresponding to different periods of contact.

From these facts, electrification phenomena are capable of receiving a mathematical rendering, which must prove of great use to telegraph engineers.

If the temperature coefficient were constant for all and every period of contact, we should obviously obtain a series of curves with ordinates increasing in a constant ratio, which would mean that the resistances did not diminish as we reach the higher temperatures. Now as the temperature coefficients for increased duration of contact diminish, the curves more nearly approach each other as the temperatures are increased, which agrees with the fact that electrification ratios are reduced less and less as the resistance itself diminishes. A very curious result arises from this treatment of the subject, which I have not yet had sufficient time to examine, but which may be mentioned here as probably it may assist us to explain something of the nature of electrification. To determine approximately the electrification ratio and consequently the resistance at any required temperature and for any period of contact, calculate first the temperature coefficient for the required temperature, which is simply the expansion of the ratio for  $1^{\circ}$  F. to that power corresponding to the degrees of difference. Using this as the factor, extract the root of the ratio for any two given periods of contact, this will give very nearly the electrification ratio corresponding to the same period of contact at the required temperature.

It thus appears that electrification, which is an inseparable property of all insulators follows some law of variation in which the temperature coefficient of the insulator itself is a function.

I hope to communicate to a future meeting the mathematical development of the application of logarithmic functions to electrification and thermal charges in insulating media.

*Notes on the Volumes of Solutions*, by J. A. Ewing and J. G. MacGregor, D.Sc.—In a paper by the authors published in vol. xxvii. of the *Transactions of the Royal Society of Edinburgh*, containing an account of experiments on the density and electrical conductivity of certain saline solutions, notice is directed to the fact that the density of very weak solutions of sulphate of copper and sulphate of zinc is greater than it would be on the hypothesis that the anhydrous part of the salt dissolves without increase of volume in the whole of the water present, including the water of crystallisation. On the other hand the density of comparatively strong solutions is less than this hypothesis would make it. From this it follows that if a small quantity of one of these salts in the anhydrous state were added to water, it would cause contraction, while a larger quantity of the salt would produce expansion. The amount of such contraction, however, as indicated by observations of density, was so small, that the authors were unwilling to speak positively as to its existence until they had applied a direct volumetric test. They have now done so, with the result of confirming the deduction drawn from their earlier experiments.

The apparatus consisted of a large bottle, 2744 c.cm. in capacity, through the cork of which projected a vertical tube of 0.66 cm. in bore. The bottle, as well as a part of the tube, was filled with distilled water, and the salt was introduced in quantities of ten grammes at a time. The resulting change of volume was shown by the rise or fall of liquid in the tube. In order to eliminate the effect of variations of temperature, a second precisely similar bottle and tube were prepared and filled with water, and the two were placed together in a large tube full of water.

The second bottle acted as a thermometer, and the expansion or contraction due to the introduction of the salt into the first bottle was indicated by the difference between the changes of level in the two tubes. After the introduction of each dose of salt the bottle was rolled about for a time, so as to secure thorough diffusion and solution, and then an interval of at least six hours elapsed before readings were taken, in order that the heat given out by the hydration of the salt might be dissipated.

The following results have been obtained in the case of anhydrous sulphate of copper:—The maximum contraction occurs when the proportion of anhydrous salt to water is about one to fifty, and the amount of contraction is then 0.00043 of the original volume of water. As more salt is added the solution begins to expand, and with one part of salt to eighteen of water the volume is equal to that of the water originally present. After

this any further addition of salt produces expansion beyond the original volume. The rate of expansion per unit quantity of salt appears to increase continually, but at first it is negative.

The above numbers are given subject to correction by more elaborate experiments that are now going on. The authors hope to extend the inquiry to other salts. They have already examined the behaviour of anhydrous sulphate of soda, but with that salt no contraction whatever has been observed; the solutions expand rapidly from the first.

*On Magnetic Induction as affecting Observations of the Intensity of the Horizontal Component of the Earth's Magnetic Force*, by Charles Chambers, F.R.S., Superintendent of the Colaba Observatory, Bombay.—The magnets used in observations of deflection and vibration, which observations are necessarily made in the field of the earth's magnetic force, are subject to the inducing action of that force; and it is the universal practice of magnetic observatories, sanctioned by the most eminent writers on terrestrial magnetism, to apply corrections on account of induction both to the deflection and vibration observations. The object of this communication is to advance theoretical reasons, supported by experimental evidence, against the propriety of the particular correction applied to the vibration observation. This correction is based on the assumption that the vibration magnet is susceptible of induction longitudinally but not transversely or not so sensibly; and the assumption probably rests on what the writer regards as a false analogy between a permanent magnet and an induced magnet. The former, when removed from the influence of a strong magnetising action, remains a magnet by virtue of its own internal forces, whilst the latter is a magnet by virtue of external forces alone; it does not therefore follow that because the power of a permanent magnet, measured by its magnetic moment, cannot be made by the same means nearly as great transversely as longitudinally, therefore the same may be said of an induced magnet. Indeed, in his treatment of the subject of the deviations of the compass, Sir George Airy gives to each elemental portion of a ship's iron as great a susceptibility to induction in one direction as in another; and in the more elaborate treatment of the same subject, in which Poisson's equations are taken as expressing the fundamental conceptions of the theory, terms representing transverse induction are still retained as of comparable magnitude in presence of others representing longitudinal induction.

Applying the Astronomer-Royal's theory to the particular case of the vibration magnet, its induced magnetism becomes an assemblage of elementary magnets, whose magnetic axes are all parallel to the magnetic meridian, and which, since they sensibly retain their parallelism to the meridian during the oscillation of the magnet, give rise to no moment of restitution, hence, according to this view, no correction would be required.

According to Poisson's theory, the amount of the correction is matter for experimental inquiry, and cannot be safely determined on *a priori* grounds. It may be objected, however, that the swinging of a ship being a slow motion compared with the oscillation of a magnet, the theory of the deviations of the compass must be modified in its application to the case in question; and this is, no doubt, a correct view, for the theory regards the inductive action as being, at every moment considered, sensibly carried to its limit of effectiveness; whilst it is not only conceivable, but doubtless the fact, that where, as with the oscillating magnet, the motion is reversed every few seconds, the transverse inductive action only partially approaches its limit. On this account we should be prepared to expect then, that even if the transverse induction were as great as the longitudinal when time for full development of the induction was allowed, it would be in defect in the case of the vibrating magnet.

In the years 1873 and 1874—long before these views of the subject of induction first occurred to the writer—he had had made in Bombay a careful comparison of two Kew unifilar magnetometers by means of practically contemporaneous observations. The result was to show a persistent difference in the values of the horizontal force yielded by the two instruments, far exceeding any probable errors of observation, and, after a careful examination of each single observational quantity and of each constant entering into the computations, the writer came to the conclusion that no error of the magnitude of that in question could have its source anywhere but in connection with the induction corrections. The values obtained for the horizontal force were, in British units of force—

With magnetometer No. 17.	With magnetometer No. 23.
8.0701 {	8.0841
8.0698 {	8.0823
8.0762 {	8.0916
8.0764 {	8.0945
8.0694 {	8.0965
8.0707 {	8.0904
8.0757 {	8.0844
8.0756 {	8.0821
	8.0902
Mean = 8.0730	8.0858
	8.0905
	8.0880
	Mean = 8.0884

No. 23 showing an excess over No. 17 of .0154 British units of force, or of .0019 of the whole horizontal force.

We observe that the greatest value given by No. 17 is less than the least value given by No. 23, and infer that the difference between the two means cannot be attributed to probable error of observation, the value of which for a single determination (about .001 of the whole force) is, moreover, much smaller. If we now remove the corrections applied for induction to the vibration observations, the mean value yielded by No. 17 becomes .0004 of the whole force greater than the mean yielded by No. 23. It thus appears that a small correction, such as we have already seen reason to expect, is required for the vibration observation, but—on an average for the two instruments employed—only of about one-sixth of the value of that which it is the custom of magneticians to apply; and as this small quantity scarcely exceeds the probable error of the mean determination of the horizontal force, it is yet premature to attribute it to any definite cause. Whilst, however, the experiments afford no sufficient reason for applying this small correction, they speak very distinctly in favour of no induction correction at all for the vibration observation as against the common practice.

To show that the error that we have been discussing is not of that minute order that is usually disregarded, we may mention that it would amount, in the case of the unifilar magnetometer used at the Observatory, to about eight times the probable error of an observation.

#### SECTION B.—CHEMICAL SCIENCE.

*On a New Mechanical Furnace used in the Alkali Manufacture, and for Calcining Purposes generally*, by James Maclear, F.C.S.—The author exhibited and explained the construction of a working model of the furnace which he has introduced for the calcination or so called carbonating of soda, ash, or alkali, and which is also applicable to many other operations, notably that of calcining copper ores, especially as required in that branch of copper manufacture called the "wet process."

These furnaces are now being widely adopted by alkali manufacturers with great success, the saving in labour having been over 60 per cent., and of coal over 20 per cent., while the quality of the work done is much superior to hand work.

*On an Improved System of Alkali Manufacture*, by Mr. James Maclear.—The author described his improved system of manufacturing blend ash or crude alkali, and claims that it has the following advantages:—

1. By its use the output of the furnaces has been increased from 50 per cent. to 70 per cent.
2. There is a large saving during the lixiviation and in coal.
3. There is a much reduced quantity of waste.
4. There is a considerably increased yield of alkali from a given amount of sulphate of soda.
5. There is a considerable saving in wages.

The process is now widely adopted in Great Britain, and is also most successfully used in France.

*On the Regeneration of the Sulphur employed in the Alkali Manufacture, by the "Maclear Process," as conducted at the works of Messrs. Charles Tennant and Co., St. Rollox*, by James Maclear, F.C.S.—The author described his process as conducted at Messrs. Tennant's works, at St. Rollox, and showed how by its adoption the nuisance arising from alkali waste deposits and the drainage therefrom had been removed. He also gave details of the cost of manufacturing sulphur by this process, and a description of the plant employed.

The "Maclear Process" is specially applicable to those cases where the drainage of the waste deposits is allowed to flow into streams or rivers, as by collecting the drainage liquor and

treating it in the manner described by the author, not only is a great source of nuisance removed, but a new outlet is obtained for hydrochloric acid, while the sulphur is produced at a cost which leaves an amply remunerative margin to the manufacturer.

Messrs. Tennant and Co. now recover weekly about thirty-five tons of refined sulphur by this process.

*The Action of Various Fatty Oils upon Copper*, by W. H. Watson.—This communication enumerates a number of experiments showing the extent to which different oils act upon copper, the conclusions arrived at being that paraffin and castor oils have the least action upon copper, whilst the action of sperm and seal oil is slight. The rest of the oils examined—linseed, olive, almond, colza, sesame, and neatfoot, all act considerably upon copper, the action of linseed oil being especially great. The author concludes from experiments that the comparative action of different oils cannot in all cases be decided upon from the appearance of the oils after exposure to copper plates, though minute quantities of the metal may be easily detected in most oils from the colour produced.

*On Changes in Candles produced by long Exposure to Sea-water*, by Prof. Gladstone, F.R.S.—Mr. Latimer Clarke had sent the author some specimens of candles recovered from the wreck of a vessel sunk off the Spanish coast in 1702, which have remained submerged for a period of 173 years. The wick has rotted away, leaving scarcely any trace of its existence, while the fatty portion has become a friable heavy substance of a dull white colour. The candles bore evidence of having been formed by dipping. The fat may be easily separated from the rest by ether.

After exhaustion with ether there remained a strongly alkaline white ash, consisting of carbonate and chloride of calcium and sodium, with traces of potassium and magnesium. From analysis it appears that the fat has been converted in great measure into calcium and sodium salts, doubtless by the slow replacement of the triatomic group  $C_3H_5$  in the stearine, by three atoms of the metal, with the simultaneous production of glycerine. Though the calcium in sea-water is far less abundant than the sodium, it appears to have had a much greater effect, and it is impossible to say whether the one salt may not have been made by double decomposition from the other. The author pointed out as an interesting point that whereas the fats have been in contact with a practically unlimited quantity of sea-water for 173 years, and a chemical change between them has been possible, the double decomposition has proceeded so slowly that the reaction is only about half completed at the present time.

*Contribution to Chemical Dynamics*, by C. R. Alder Wright and A. P. Luff.—Guided by certain theoretical speculations, the authors are endeavouring to trace out the connections between the chemical habits of certain substances and the temperatures at which their mutual inter-reactions are first noticeable, and notably the relations between the heat developed during their actions and these temperatures of initial action. Experimenting on oxides of copper and iron in different condition as to molecular structure, they find, that whilst the initial temperature of action varies within certain limits with the molecular state of the metallic oxide, when they are subjected to the ordinary action of carbon dioxide, hydrogen, and carbon, a given form of either oxide is invariably acted on by carbon dioxide at a lower temperature than by hydrogen, and by hydrogen than by carbon; whilst the heat evolution during the reduction of the metallic oxide by carbon dioxide is always greater than that during reduction by hydrogen, which again is less than that during reduction by carbon. Similarly, so far as they can be compared, that metallic oxide is acted on at a lower temperature, in the production of which there is less heat evolution (*i.e.*, in the reduction of which there is most heat evolution). How far these generalisations are applicable to other metals is under examination, as are several other collateral points.

*On the Coal brought Home by the late Arctic Expedition*, by T. Wills.—The coal occurs on the side of a narrow mountain gorge about two miles from Discovery Bay, the winter quarters of H.M.S. *Discovery*. It appeared in the form of a slight saddleback thickest in the centre, becoming continually smaller at each end; the thickness of the seam at the deepest visible portion was 25 feet, and its visible length 250 yards; neither the bottom of the seam nor the underlying strata were visible at any place. Overlying the coal was very friable carbonaceous shale containing impressions of miocene plants, and above this shale a hard fossil red clay stone similar to the red miocene rock of the Disco coal beds, but sterile. The seam is almost uniform in character, and is very free from clayey veins. On obtaining the

sample of coal Mr. Wills expected to find it to be a lignite, as cretaceous or tertiary brown coal does occur in these high latitudes, and more especially as the impressions of miocene plants in the overlying strata seems to indicate a more recent period than the true carboniferous; but it turns out that this is not the case, for the coal in appearance and on analysis cannot be distinguished from a bituminous coal of exceedingly good quality belonging to the true carboniferous period. Mr. Wills, from recent information, understands that miocene plants have been found in the strata underlying the coal, in which case there can be little doubt that the coal is a miocene coal, although differing greatly from most specimens of such coals. The following is the result of several analyses:—

Specific gravity	...	...	...	...	1·29
Moisture	...	...	...	...	2·38
Ash	...	...	...	...	6·21
Sulphur	...	...	...	...	.96
Carbon	...	...	...	...	76·95
Hydrogen	...	...	...	...	5·43
Oxygen	{ by difference	...	...	...	6·78
Nitrogen		100·00			

On comparing these figures with the result of the analyses of a mixture of thirteen different seams from English coal-fields, Mr. Wills has found that the Arctic coal possesses very nearly the same composition.

*On Hederic Acid and Resin of Scammony*, by C. T. Kingzett.—In a paper *On some New Reactions in Organic Chemistry*, and their ultimate bearings the author in conjunction with Dr. Hake has described a number of instances in which bodies, for instance camphor, gives with strong sulphuric acid and sugar a violet-coloured product. Other bodies give this colour with sulphuric acid without the addition of sugar, and by means of these reactions the constitution of many substances may be in a measure predicted. Hederic acid,  $C_{16}H_{28}O_4$  (Posset, also Davies), a constituent of ivy leaves, gives this colour best with sulphuric acid, and so also in a less degree does resin of scammony. In the present paper the author describes the process by which he has isolated glucose from these respective substances, thus confirming the hypothesis given in his original paper alluded to. Incidentally it is shown that the root of the convolvulus scammonia contains no alkaloid, and some information is given regarding a volatile oil obtained below 90° on distillation of scammony resin.

*Albumen of Commerce*, by C. T. Kingzett and M. Zingler.—In the patent process described by the authors, albumen solutions are bleached and preserved by passing a current of air through them in presence of oil of turpentine at a temperature of about 40° C. Under these conditions the turpentine oxidises, producing hydrogen-peroxide, camphoric acid, &c., the former of which bodies effects as it forms the bleaching of blood serum or other albuminous solutions, while the camphoric acid, &c., preserves them in the liquid condition entirely free from putrescible or other changes.

*Alkaloids from Japanese Aconite*, by Dr. Paul and C. T. Kingzett.—The authors have isolated from Japanese aconite an alkaloid of the formula  $C_{29}H_{43}NO_9$  which is crystalline, but does not form crystallisable salts. They also show that when the alkaloidal principle is extracted by Duquesnel's process it is accompanied by the salt of an alkaloid, perhaps aconitite of aconitine; and from this it is suggested that the so-called aconitine obtained and analysed by Wright and others, has never been obtained absolutely pure, being probably a variable mixture of the alkaloid with the above salt.

*Further Researches on Aconite Alkaloids*, by Dr. C. R. Alder Wright and A. P. Luff.—Aconitine,  $C_{33}H_{43}NO_{12}$ , the active principle of *Aconitum napellus* is readily saponified by heating with water acids and alkalies into benzoic acid, and a new base termed by the authors *aconine* pseudoaconitine,  $C_{38}H_{49}NO_{11}$ , the chief active alkaloid of *A. ferox*, similarly gives rise to *dimethylproto-catechic acid* and *pseudoaconine*,  $C_{27}H_{41}NO_8$ . These two decomposition products, aconine and pseudoaconine, are comparatively inert physiologically. A number of their compounds and derivatives have been studied and a method for the approximate analysis of the impure alkaloids met with in commerce under the name "aconitine," has been devised, based on the quantitative estimation of the benzoic and dimethyl proto-catechic acids formed on saponification.

*On Pyrocatechin as a Derivative of Certain Varieties of Tannic*

*Acid*, by John Watts, D.Sc.—From the known reactions of gallotannic acid and catechutannic acid, and of their derivatives, the author considered it probable that all the blue producing tannins would yield pyrogallol on distillation, while the green producing tannins, would yield pyrocatechin: an experiment such was found to be the case. The gallotannic acids distilled were,—valonea, oak-bark, divi, myrtolaves, sumach, and mimosa bark; and the mimotannic acids, rhatany, tormentil, and hemlock bark. The yield of pyrocatechin from rhatany was very considerable.

These results point to the conclusion that the blue- and green-producing tannins are related to each other in the same manner as pyrogallol and pyrocatechin. The author anticipates being able to bring forward shortly further experiments in support of this view.

*On the Formation of the Black Oxide of Iron on Iron Surfaces for the Prevention of Corrosion*, by Prof. Barff, M.A. (Cantab.)—The author pointed out the cause of his many failures in his first experiments and the failures which others had experienced in obtaining a perfectly adherent and coherent coating of black oxide, as arising from moisture in the steam with which the articles operated on were oxidised. When perfectly dry steam is used and no air admitted into the muffle, or oxidising chamber, then in all cases a perfect protecting film is formed. The process is exceedingly simple: a wrought-iron muffle containing the iron articles to be operated upon, is heated to a dull red heat, all the openings closed, and dry steam turned in, and the muffle kept filled with the steam during the whole operation, which lasts from three to five hours; the fire is then raked out, and the articles allowed to become black in an atmosphere of steam; after this the steam is turned off, and the muffle and its contents are allowed to cool slowly. The temperature to which the muffle is heated varies according to the nature of the articles operated on—from 350° to 700° C. More recent experiments seem to show that the process may be further simplified by using superheated steam of such a temperature that the external application of heat to the muffle is unnecessary. A considerable number of cast-iron, wrought-iron, and steel bodies which had been coated were exhibited. Many of these had been out of doors for months; others had been kept in fresh water or in sea-water for a similar length of time, but not the slightest indication of further oxidation was visible. Even strong nitric and sulphuric acids are without action on this coating of black oxide.

#### SECTION C.—GEOLOGY.

*The Post-tertiary Fossils procured in the late Arctic Expedition; with Notes on some of the Recent or Living Mollusca from the same Expedition*, by J. Gwyn Jeffreys, LL.D., F.R.S.—The fossils were collected by Capt. Feilden and Mr. Hart, the Naturalists of the Expedition, and by Lieut. Egerton and Dr. Moss, two of the officers of H.M.S. *Alert*, in very high latitudes, viz., between 82° and 83° N.L. The furthest point reached by the Expedition was 83° 20' 26". These fossils were found in mud-banks or raised sea-beds at heights ranging from the level of the sea to 600 feet above it. They consisted of eighteen species of mollusca, one of actinopoda, one of foraminifera, and one of marine plants, being altogether twenty-one species, all of which now live in the Arctic seas. The author gave a list of the species, and showed their distribution in a recent or living as well as fossil state; and he added some remarks as to the recent mollusca procured in the Expedition, and as to the apparent abundance of marine animals in the "Palæocystic Sea" of Sir George Nares. Prof. Rupert Jones, Dr. Moss, Mr. Woodall, and Mr. De Rance took part in the discussion which ensued on the reading of this paper.

*Sketch of the Geology of the Coast from the Rame Head to the Bolt Tail*, by W. Pengelly, F.R.S.—Mr. Pengelly expressed his partial acceptance of Mr. Jukes' views. He believed the upper old red sandstone to be the equivalent of the lower Devonian, each containing *Phyllolepis concentrica*, which is not found at any other horizon. The author also called attention to the metamorphism which has taken place in the rocks at and near Prawle Point, for which no sufficient cause is now apparent. He supported the suggestion of Dr. Holl and Mr. Jukes that south of Prawle Point there may be a boss of granite now submerged, to which the change in character of the rocks is due. As evidence of this he spoke of a beach, in which many granitoid pebbles occur, but with this exception the pebbles are strictly local. He

thought that these pebbles were probably derived from the now submerged granite. The age of the metamorphism is clearly pre-triassic, for the triassic strata of the district contain pebbles of metamorphosed rock.

*On the Drift of Plymouth Hoe*, by J. H. Collins.—The author stated that excavations were nearly always going on in the neighbourhood of Plymouth Hoe, and that fresh sections of the so-called raised beaches and glacial deposits were continually being exposed.

He had lately visited the Hoe, Mt. Batten, and Deadman's Bay, in company with Mr. Whitley of Truro, and had found gravels, sands, and clays lying in the hollows of the limestone, and filling fissures and caverns. The gravels were sometimes cemented by stalagmite into a conglomerate. The pebbles were composed of quartz, limestone, tourmaline schist, greenstone, blue and red grit, hard clay-slate, schorl rock, granite, elvan, flint, chert, stalagmite, and one pebble of granite; all of which the author considered had been derived from the rocks of the neighbourhood within a few miles. None of the pebbles were in the least degree ice-scratched, and there were very few angular fragments of any kind.

The gravels had yielded bones of rhinoceros, elephant, and other animals of the so-called "Mammoth period." The author discussed the evidence of local denudation, and adopted or arrived at the following conclusions:—

1. The deposits are not raised beaches.
2. They are not glacial.
3. They were formed rapidly.
4. Gravels, fissure deposits, and cave deposits are of the same age.
5. That they belong to the Mammoth period.
6. There is no evidence in the immediate neighbourhood to carry back their formation more than a few thousand years.

*Notes on the Devonian Rocks near Newton Abbot and Torquay, with Remarks on the Subject of their Classification*, by H. B. Woodward, F.G.S.—After having alluded to the imperfect state of the information respecting the Devonian rocks, especially in regard to local details of structure, the writer pointed out that the succession of strata near Newton Abbott and Torquay was (in descending order) as follows:—3. Limestone; 2. Slates; 1. Red Sandstones. He noted the resemblances in lithological characters between these beds and the lower carboniferous rocks and old red sandstone, with which they were classed fifty years ago by De la Beche. He likewise drew attention to their relations with the Culm measures, observing that while there were indications of conformability to them, no positive proof to the contrary had been established; and the supposed instances of unconformability were all of them, as Jukes had considered, capable of explanation by faults and other disturbances. Attention was drawn to some striking cases of such phenomena. The impossibility of accepting fossil evidence alone was insisted upon, inasmuch as its value in classification could only be gained after the stratigraphical relations of the beds had been made out, and at present the exact horizons from which many of the species had been collected was not determined.

Further, the theory that the Devonian rocks were the equivalents in time to the old red sandstone required the existence at this period of a great barrier between the marine deposits of the former group and the freshwater accumulations of the latter, and there was no physical evidence in support of this. Taking all the facts into consideration, Mr. Woodward argued that they were in favour of the classification proposed by Jukes, which regarded the lowermost Devonian rocks as old red sandstone, and the slates and limestones as lower carboniferous, formed in an area which constituted a zoological province differing to some extent from that in which these rocks were deposited further north in the British area.

*On the Devonian System in England and Belgium*, by Prof. G. Dewalque.—Having surveyed, last year, the Devonian system of this country, I avail myself of the meeting of the British Association to offer a few remarks on the results of my survey. As my visit was short I cannot lay claim to a minute acquaintance with this great formation in England; but, as well acquainted with it in Belgium and the Rhenish provinces, I hope the following remarks may prove of some interest to the Association:—

I had not time to visit South Devon. As regards North Devon my conclusions are as follows:—1. The metamorphic character is more prevalent there than in Belgium, especially in the middle and the upper divisions. 2. All this series is perfectly continuous, from Barnstaple to Lynton. Nowhere is there

a reappearance of such identical rocks as to prove a fault, by repetition of the series. 3. The sandstones of Baggy Point and Marwood (*Cucullaea zone*) perfectly agree, both lithologically and palaeontologically, with certain portions of our "Psammites du Condros." The red sandstones of Pickwell Down correspond to the lower part of these Psammites. 4. The limestone of Ilfracombe represents, as has been previously stated, on palaeontological evidence, the "stringocephalus limestone" (*Calcaire de Givet*) of Belgium and Germany; but the lithological appearance of the rock is very different. Hence it is easy to compare this Devonian series with that of the Continent. In this respect I differ but little from Mr. Etheridge. 5. The Devonian limestone is much more abundant on the Continent than on this side of the Channel. I think, moreover, that the same is to be said of the carboniferous formation, that is to say, the mountain limestone is replaced in North Devon (at least in part) by the beds of Barnstaple and Pilton. In the slates of Pilton I found beds and nodules of siliceous concretions, which represent, I think, the *chert* of the carboniferous limestone, or the so-called *phthaniates* of our "calcaire carbonifère."

As to the old red sandstone I spent a week in Hereford, but saw very little of it. I could only hammer conveniently the "cornstones," of which I had from the descriptions a very imperfect notion. Such limestones occur identically in Belgium, with red shales, sandstones, and conglomerates in the northern trough, or "bassin de Namur." This fact seems to me of the highest value, for it leads me to this paradoxical conclusion: the old red sandstone of the United Kingdom is a marine formation, probably formed in the same ocean as the Devonian. The old red of Belgium lies regularly between limestones with *Stringocephalus Burtini* and others with *Spirifer disjunctus*. That is certainly a marine formation, and the same must be the case with the English old red sandstone.

*On the Succession of the Palaeozoic Deposits of South Devon*, by A. Champernowne, M.A., F.G.S.—The Great Devon limestones, the author concludes, are, as Mr. H. B. Woodward has said, the highest rocks of South Devon, and the belief in a series of slates and red sandstones overlying them, is a fallacy. The beds which do succeed the limestones are the Culm measures (upper carboniferous), and from the field-work of Messrs. Woodward and Read there is reason to believe them perfectly conformable. In this case the difference between the Devonian and carboniferous limestones would be one of life distribution—a geographical, and not a chronological, difference. This would probably have been long ago recognised had the characteristic ichthyolites of the old red occurred in the Staddon beds.

*Note on the Carboniferous Coast-line of North Cornwall*, by S. R. Pattison, F.G.S.—The portion of coast described extends from near Bude to Boscastle, and belongs to the formation first identified by Prof. Sedgwick in connection with the diagnosis made at Bideford by him and Sir R. Murchison as culm, or lower coal measures. Bude lies in or on the centre of the formation. The strata have a general northerly dip, and proceeding southwards down the coast of course lower beds become exposed. The Bude beds contain thin films of culm, with associated plant-remains in a very fragmentary condition. Prof. Morris many years ago in a note published in the *Proceedings of the Geological Society of Cornwall*, identified some of those remains as *Calamites*, *Sigillaria*, and *Asterophyllites*. Prof. Hull states the number of species in the North Devon beds, of which these are the continuation, at twenty-three, and Mr. Townshend Hall at twenty-six. The Bude beds are continued by foldings and succession downwards, but on arriving at St. Gennys a system of deep-blue schistose sandstones appear and form the base line of the cliff along the remarkable coast landslip which extends for two miles. From these dark-blue beds fragments or nodules containing *goniatites* appear on the beach. Then comatite-beds extend from Carne Head to the cliffs in the parish of St. Juliott. They are most abundant at the St. Gennys end of the landslip. Here, at a sand-path descending to the beach, on the beach, are huge fragments of fallen rock containing very fine large impressions of plants, especially *sigillaria*. Proceeding towards Boscastle, at the gloomy gorge of Pentaglion, the soft black shales, so characteristic of Boscastle, form the bulk of the cliffs, but below them rises a silty rock once quarried, and in this I found the usual fragmentary plants of the Bude rocks. This, with the associated soft black beds, is the farewell rock of the carboniferous, for at the cliff, on the south side of Boscastle, slates arise under the black shales, which at the summit contain

traces of crinoids, and are the commencement of the Devonian strata, continued hence to Tentagel, and well known as Devonian.

These few facts seem to verify the general conclusion arrived at by former observers, and, when more fully investigated and the fossils identified, will help to correlate the carboniferous of North Cornwall with the divisions now established elsewhere. They seem at least to show that there are provinces in our local geology still holding out temptations of further conquest to the geological explorer.

*Notes on the Palaeontology of Plymouth*, by R. N. Worth, F.G.S.—This paper did not enter into any controverted questions of stratigraphical geology, but simply noticed the main features of the palaeontology of the limestone of Plymouth and its associated rocks. The Plymouth rocks were commonly classed as Middle Devonian, and consisted of slates, limestone, and slates and sandstones, in order from north to south. The northern slate rocks did not locally contain fossils; but in the vicinity of Saltash, &c., they did. The Plymouth limestone formed a band nearly half a mile in width and nearly six and a half miles in length. It originated clearly enough in a fringing coral reef, and in its origin and constitution was therefore essentially organic. The rocks on the south of the limestone were of a more complicated character than those on the north. Slates, limestones, shales, grits, ash-beds and sandstones, alternated with each other in remarkable fashion, while faults and contortions by no means solved the riddle. These rocks in part were largely fossiliferous. In the variety of its organic remains the Plymouth limestone was not so rich as most of the other chief limestone districts of South Devon—Wolborough and Barton, for example; but those that did occur were for the most part abundant. The leading peculiarity was that while at the western end of the limestone—that was to say, at the Dockyard, Mount Wise, and at Stonehouse, in the quarry behind St. George's Hall, molluscs of various kinds occurred, at times in great profusion; at the eastern end of the limestone—Cattedown, Oreston, &c., they were comparatively rare, and over considerable areas altogether absent. And in like manner, the branching corals were found chiefly at the western end of the limestone; and the genuine reef builders at the eastern. There did not appear to be any difficulty, however, in accounting for this. Molluscs could only find a habitat on the exterior portions of the reef, and it was evident that the eastern section of the limestone more particularly had been subjected to a considerable amount of denudation, and that the outer beds had to a large extent been removed. Bivalves and univalves were rarely associated, but kept to distinct areas, where they sometimes occurred in great abundance. The peculiar interest of the palaeontology of Plymouth consisted in the products of the ossiferous caverns and fissures at Oreston, the Hoe, and Yealmpton, including the bones of the mammoth, *Hippopotamus* (?), *Rhinoceros tichorhinus* and *leptorhinus*, cave lion, cave hyæna, cave bear, ancient bear, the lesser bison, long fronted ox, horse, ass, &c., and a vertebra of the whale.

*On the Geological Significance of the Result of the Boring at Messrs. Meux's Brewery, Tottenham Court Road*, by R. A. C. Godwin-Austen, F.R.S.—It is now very generally known that this undertaking, after passing through great thicknesses of chalk, met with a very insignificant representative of the sands which underlie the chalk in the south-east of England, and thence passed at once into strata which, by characteristic fossils, were identified as of upper Devonian age. This is just as had been anticipated as to the absence of any portion of the colitic series there,<sup>1</sup> and confirmed what many years since had been supposed to be the subterranean structure of the south of England; indeed, it may be fairly stated that geologists generally have been of opinion that a band of palaeozoic rocks, extending from Westphalia westwards, passed somewhere beneath the secondary formations of the south-east of England.

The importance of determining the course of such palaeozoic band was, that along the whole of the exposed part of its course, as from its extreme eastern place to near Valenciennes, it had dependent on it, on the north, the productive coal-measures of Westphalia, Belgium, and the north of France. From Valenciennes westwards the coal-measures are not exposed at the surface, but are reached beneath the chalk formation; but from the underground workings at Douay, Béthune, &c., the relation of the several members of the palaeozoic series are known to correspond exactly with those where the series is exposed; as is the case also where they are again seen at the surface in the

Boulois, and at sundry other valleys of elevation along the axis of Artois.

The whole of the coal-measures of Belgium and the north of France must be understood as occupying a trough formed out of the older members of the great palaeozoic series, and the explanation given of the preservation of this extended and narrow band of coal-growth surface is that it has resulted from a contraction of the earth's crust in a south to north direction, at some time subsequent to the completion of the palaeozoic series (coal-measures included), whereby along this line a series of east and west undulations were produced, in the deepest or most considerable of which, portions of the coal-growth surfaces became included so as to be preserved during the subsequent periods of denudation and removal.

From the consideration of the physical features of a line of country of elevation and disturbance, which crosses the European continental area for 300 leagues, it was inferred that like results were due to like causes here; the line of under-run of the palaeozoic strata was conjecturally carried along by where it has just been met with; so it may reasonably be supposed that certain other phenomena which in like manner have resulted from the same disturbances should also correspond, and serve for guidance.

For the present it has not been ascertained in what direction the highly-inclined Devonian strata at Tottenham Court Road were dipping, a most important point in the considerations involved. It may safely be supposed that from their position any palaeozoic rocks at such place must be trending east and west. The occurrence may seem to be an isolated fact, but there are other inferences which tend to give it importance.

The 653 feet of chalk strata were horizontal, or with only a very slight north dip. The Devonian strata gone through dipped uniformly at an angle of 30°. The section therefore corresponds exactly with those of the north of France.

In Belgium, and the north of France, it is on the south side of the palaeozoic trough that the high inclines occur, as happens along the whole line from Liège to Trelon. On the north the beds are flatter and spread out wider. From this it may be supposed that it was the north side of the trough which was hit upon at Messrs. Meux's, and that it is a trough at this place follows necessarily from the circumstance that the beds so highly inclined were as low as the Devonian.

Bearing in mind that the whole of this part of Europe we are now considering formed part of the area over which the Devonian or lower carboniferous series preceded or was overlaid by the upper or true carboniferous formations, and that where one occurs the other follows everywhere, the fact of the inclination of the beds at Tottenham Court Road involves this, that the higher portions must soon follow—the mountain limestone on the Devonian, and the coal-measures on the mountain limestone.

This reasoning applies equally whether the Devonian strata at Tottenham Court Road may be dipping north or south, but thus much has been ascertained, that London just overlies the edge of a great coal-field, and the probability is that the coal-field lies to the north.

What seems to suggest that the coal in this direction may have considerable extension is derived partly from a study of the geological features of our own island, and partly from what is the case in Belgium. It is dependent on what was the original form and extent of the coal-growth surface, and on the places at which the greatest amount of contraction and subsequent denudation of the surface took place.

Mr. Whitaker described the deep borings around London, and gave an account of the strata traversed by them. He suggested that some of them should be continued deeper, and thought that in place of a "Sussex boring" or a "Kentish boring" they ought to have a general scheme for investigating the range of the palaeozoic rocks. Mr. Lebour suggested that under London (as often occurs in Belgium) the rocks might possibly be inverted or reversed by oblique faults, so that Devonian rocks under certain circumstances might overlie the coal-measures. Mr. Topley, in reply, defended the past action of the Sub-Wealden Committee.

*On a New Method for Studying the Optical Characters of Minerals*, by H. C. Sorby, F.R.S.—The author first described the principles on which this method depended, and showed that the great difference between the appearance seen with the naked eye and the microscope is due to the object-glass being able to collect divergent rays. In looking with a low magnifying power at a small circular hole seen through a section of a crystal, very different phenomena present themselves, according to its optical

<sup>1</sup> See "Report of Coal Commission," vol. i., pp. 431-432.

characters. If it has no double refraction, only one well-defined circular hole can be seen. If the mineral possess double refraction and only one optic axis, like calcite, two images of the hole are seen. If the section be cut perpendicular to the axis, two circular holes are seen directly superimposed, but at two different foci. If the section be in the plane of cleavage, two widely-divided images are visible, the one due to the ordinary ray being circular, and the other, due to the extraordinary ray being distorted and drawn out in two opposite planes at two different foci. When the section is cut parallel to the axis, this image due to the extraordinary ray is still more elongated, but the images are directly superimposed. We thus at once learn that the mineral has double refraction, has an optic axis, and also what is the direction in which the section is cut. In the case of crystals like Arragonite, which have two optic axes, there is no ordinary ray, and at the focal points we see the circular hole drawn out in opposite planes into crosses. The character of these crosses depends upon the direction of the section, but the fact of the crosses being seen at once proves that the mineral has two optic axes. Some facts are better observed if, instead of a circular hole, we examine through the crystalline plate a grating with two systems of lines at right angles to one another. We then obtain what the author calls unifocal or bifocal images, according to the systems of crystallisation. Crystals without double refraction have only one unifocal image; crystals having one optic axis have one unifocal and one bifocal image; whereas crystals having two optic axes give two bifocal images. The definition of unifocal images is independent of the position of the lines, whereas in the case of bifocal images the lines are distinctly visible only when they are parallel or perpendicular to a particular axis of the crystal, and, spread out, become obscure and disappear when rotated to a different azimuth.

The above-named general characters differ so much in different minerals, that they furnish a most valuable means for their identification.

*On the "Great Flat Lode" South of Redruth and Camborne,* by C. Le Neve Foster, B.A., D.Sc.—In this paper the author described an important tin lode which is wrought in various places for a distance of three and a half miles. In some places it occurs, for instance at Wheal Uny, at the junction of the clayslate (killas) and granite, but in other mines it lies entirely in granite.

Its characteristics are:—

1. A leader of true fissure vein, generally only a few inches wide, and filled with clay, fragments of the inclosing rocks, and tin or copper ores, dipping 30° to 50° S., and striking from 20° to 45° N. or E. (true).

2. The lode, from four to fifteen feet wide, on one or both sides of the leader, consisting mainly of schorl-rock, containing grains and veins of tin ore. It yields from 1 to 3 per cent. tin ore.

3. A capel, or non-stanniferous or slightly stanniferous schorl-rock, separating the lode from the killas or granite.

4. Absence of any wall or plane of separation between the lode and capel, or between the capel and granite. The author said that all the appearances pointed to the fact that the lode and capel are merely altered granite. In confirmation of this view he explained that he had found cavities in the lode resembling felspar crystals in shape, and probably left by its removal; furthermore the microscopic examination of the capel shows apparently pseudomorphs of quartz after felspar.

If it is admitted that the mass of the "Great Flat Lode," and its capels are altered rocks once containing felspar, we are driven to conclude that that rock must once have been granite, because of the gradual passage of the capel into granite. Supposing this view to be correct, we must adopt a similar explanation in the case of many of the important tin lodes in Cornwall.

The author ventured the opinion that half the tin ore obtained in Cornwall is now derived from altered granite.

*On some Tin Mines in the Parish of Wendron, Cornwall,* by C. Le Neve Foster, B.A., D.Sc.—The author described the tin deposits of the following mines:—Balmyneher, the Lovell, and South Wendron. The author supposes that the tinny rock is an altered granite, and he brings forward in support of his argument the fact that pseudomorphs of quartz and of gilbertite after orthoclase, are found in the stuff from the Lovell, and that there is a gradual passage from the tin rock into granite.

*On some of the Stockworks of Cornwall,* by C. Le Neve Foster, B.A., D.Sc.—The author divided the tin stockworks into three classes according as they occur in killas granite or elvan, and then described the mode of occurrence of tin ore at some of the most important.

*The Carboniferous Limestone and Millstone Grit in the Country around Llangollen,* by G. H. Morton.—The author described the carboniferous limestone exposed in the Eglwyseg ridge near Llangollen, North Wales. He stated that the finest section is exposed at the Ty-nant ravine on the bed of Cefn-y Fedw, and that the country around must be considered as the typical area of the lower carboniferous series of North Wales. The millstone grit or Cefn-y-Fedw sandstone, which repose on the limestone in the same district, was also described. The following tabulation explains the succession and thickness of the entire series:—

*Tabular View of the Carboniferous Limestone and Cefn-y-Fedw Sandstone in the Country around Llangollen.*

	feet.	
Aqueduct grit or upper sandstone and conglomerate ... ... ...	70	Upper Cefn-y-Fedw, Dee Bridge, or millstone grit series.
Upper shale ... ... ...	30	
Dee Bridge sandstone ...	30	
Cefn-y-Fedw sandstone.		
Lower shale with fire-clay and bands of limestone.	18	Middle and lower Cefn-y-Fedw or Yoredale series.
Middle sandstone ... ...	200	
Cherty shale ... ... ...	50	
Lower sandstone and conglomerate ... ... ...	250	
Sandy limestone ... ...	75	
Carboniferous limestone.		
Upper grey limestone ...	300	Upper carboniferous limestone.
„ white „ „	300	
Lower „ „ „	120	Lower do.
„ brown „ „	480	
	1923	
Upper old red sandstone	300	

The following table shows the gradual attenuation of the carboniferous limestone towards the south-east.

*Attenuation of the Carboniferous Limestone.*

Subdivision.	Ty-nant.	Tan-y-Castell.	Trevor Rocks.	Bron-henlog.	Fron.
Upper grey limestone,	300	300	250	66 <sup>1</sup>	88 <sup>1</sup>
„ white „	300	250	140	99	27 <sup>2</sup>
Lower „ „ „	120	115	117	104	"
„ brown „ „	480	360	100 <sup>3</sup>	26 <sup>3</sup>	"
	1200	1025	607	295	115

This section shows how the limestone diminishes in thickness with the rise of the Wenlock shale towards the south-east. Between the Ty-nant ravine and Tan-y-Castell it has thinned out 200 feet, and at Fron-y-Cysyllte, four miles from the former place, the attenuation is not less than 900 feet.

The list of fossils collected by the author contained seventy-eight species. Of these fifty-eight occur in the upper grey limestone and only eighteen in the lower brown limestone. If the carboniferous limestone is simply divided into upper and lower limestone, thirty-eight species are peculiar to the two upper subdivisions and nineteen to the two lower subdivisions—twenty species being common to both. However, the species are by no means confined to the subdivisions in which they are found near Llangollen, for they occur at different horizons in other districts.

*On the Occurrence of Branchipus or Chirocephalus in a Fossil State in the Upper Part of the Fluvio-Marine Series (Middle Eocene), at Gurnet and Thorness Bays, near Cowes, Isle of Wight,* by Henry Woodward, F.R.S.—Mr. Woodward referred to the great interest surrounding the geology of the Isle of Wight from the labours of Ibbetson, Forbes, Mantell, Prestwich, Bristow, and many others, and the rich fauna contained in its strata, much of which still remains to be described, although the stratigraphical geology has been well worked out by the officers of the Geological Survey. Mr. Woodward called attention to a thin band of freshwater limestone occurring [at the base of the cliff, belonging to the Bembridge series, from two to twelve inches thick, which at places is full of remains of plants and insects. *Dytiscus*, *Curculio*, *Formica*, &c., and what is most remarkable, the diaphanous bodies of a small phyllopod crustacean, without a hard shelly covering. This little crustacean is closely related to the "Brine-shrimp" (*Artemia salina*), so

<sup>1</sup> Upper portions been denuded.

<sup>2</sup> Reposes on the Wenlock shale.

<sup>3</sup> Base not ascertained with certainty.

abundant in the brine-pans at Lymington at the present day. *Branchipus*, or *Chirocephalus*, is a freshwater crustacean found living in ponds in Devonshire and Kent. Its preservation is due to the admirable nature of the fine argillaceous-calcareous rock, in which it has been entombed in such numbers, the delicate outline of its gill-feet being stained with iron, so as to be as well shown as in a photograph.

#### SECTION G.—MECHANICAL SCIENCE.

*On Compound Turbines*, by Prof. Reynolds.—The combination of centrifugal pumps not having hitherto produced the anticipated results, the author had endeavoured to discover the cause of the apparent anomaly, being satisfied that theoretically the increase in the number of pumps should produce a proportionate increase in the quantity of water raised. Properly connecting his pumps, the result was as theory had justified him in expecting; and the reason why others had failed to attain the same end was that the supply of water had not been adequate, and air had got in instead of water.

*On the Difference of the Steering of Steamers with the Screw reversed when under Full Way, and when Moving Slowly*, by Prof. Osborne Reynolds.—Referring to the Report on this subject the author said the fact that the results which had been established by the Committee were so little known to pilots and seamen, besides being likely to excite surprise, would tend to cast a certain amount of discredit, if not on the truth of the results themselves, at least on their importance. It seemed as if nautical men must have formed their opinions from experience, and such was the faith of the English people in the practical that it was very difficult indeed for them to believe that a few landsmen, calling themselves scientific, could teach sailors how to steer ships. So strong was this feeling that it was to collisions they must look in the hope of preventing collisions. This sounded like a bull, but it was perfectly true, for nothing but disasters would awake our rulers to the idea that something was wrong. Fortunately, or unfortunately, such disasters were not wanting. There were the cases of the *Ville du Havre* and the *Loch Earn*, in which the collisions were undoubtedly due to the steamers having turned in the opposite direction to that intended. These and other disasters furnish evidence enough of the mistakes which had been perpetrated, and of the importance as well as the truth of the results the Committee had established. He fancied that the ignorance which existed was due to the fact that few seamen had turned a ship under full way with the screw reversed, and contented themselves by arguing as to what must happen in such a case from their experience in manoeuvring their ships when moving slowly. Of such manoeuvres they had had abundance, but as soon as they got beyond their experience, they adopted the seemingly obvious, but entirely erroneous opinion that the way of the ship would cause the rudder to act as if she was going ahead in spite of the screw being reversed. He felt strongly that in speaking thus in a town like Plymouth he ran the risk of being looked upon as impertinent. If he were wrong he was impertinent, and no one would feel it more than he should. It was not a pleasant task to point out imperfections, however accidental they might be. Even if one saw the wheel coming off an omnibus, all the thanks he was likely to get for pointing it out to the conductor was to be asked if he could not tell him something he didn't know. Of course they must learn as they went on, and all he, with deference, asked of seamen was to try the experiments for themselves, and then aid the Committee in bringing facts under the notice of the Legislature. Their own interests demanded this, for as things now were great injustice might be done to the captain who in a case of emergency adopted the very best course to save his ship.

Mr. William Froude thought the question which Prof. Reynolds had so ably dealt with of immense importance, and deserving minute consideration. Having himself had some experience of small steam launches, he had been surprised at the effect produced by the working of the screw, so that he concurred with the conclusion at which Prof. Reynolds individually, and the Committee collectively, had arrived. If sailors would occasionally listen to the advice of outsiders, it would do them no harm. Ignorance as to the effect of reversing the screw upon the way of a ship would often lead a captain into danger which might be avoided.

Sir William Thomson urged that the Committee should be reappointed, so that the Admiralty might have another opportunity of confirming or refuting the conclusions. This was

undoubtedly nothing less than a national question, for the conflict now going on between Russia and Turkey proved that skill in manoeuvring was of vital importance in torpedo warfare. In olden times the glory of England was maintained by the facility with which her ships were manoeuvred, our navy being a match against the navies of all the world in this respect, and he hoped nothing would occur to destroy that pre-eminence.

*On the Resistance of Ships*, by Mr. William Froude, F.R.S.—The object of the paper was to show the effect produced on the resistance to a ship's motion by the lengthening or shortening of the flat middle body between the bow and stern. The results were based upon experiments made at Chelston Cross with models having the same ends, but different lengths of parallel body inserted amidships. By separating the effect of the frictional skin resistance, which was proportional to the wetted surface, he proved that the increase or diminution of the power required to propel a ship, in consequence of the alteration of the length of the parallel body, depended very largely on the coincidence, or want of coincidence, of the wave crests travelling alongside the ship with the points at which the reduction of breadth by the fine lines began. When this diminution coincided with a wave crest there was no loss, but rather a gain of speed; while when it coincided with a wave hollow the loss of speed, or increase of resistance, was considerable.

*The Elevated Railway of New York*, by Capt. Douglas Galton.—The first portion of this railroad was completed for steam-traction at the beginning of 1872, and was originally constructed for a rope railway, which did not prove successful. This section consisted of single "Phoenix" columns, nine inches in diameter, spaced from 26 to 30½ feet apart along the axis of the roadway, and carrying two pairs of rolled deck or "I" beams of shallow depth, one pair under each rail. This structure was originally deficient both in vertical and lateral stiffness. The deflections of the girders were too great, and the oscillations of the columns too large. In the next alteration the columns consisted of clusters of round solid wrought iron bars, four and a quarter inches diameter, grouped by two and by four, braced together so as to form a single support, and carrying rolled channel bearers, two under each rail. The bars were bent so as to branch like a V at the top, the columns composed of two bars forming a bracketed support under the beams, and those composed of four bars giving longitudinal stability to the structure. Although imperfect and needlessly expensive, this style of column might be considered the parent of all subsequent improvements, and to have furnished a valuable hint for future designs. The line was single with sidings to allow trains to pass. Its length, including the sidings, was 7½ miles, but it was now proposed to double the line throughout and extend it. The atmospheric brake, which was in use upon all trains on the line, placed them entirely under the control of the engineman, and was so effective that a train moving at a maximum speed could be brought to a full stop in a distance barely exceeding its length. The cost of this elevated railway for a double line was estimated at about £55,600. It was simple in construction, and did not much interfere with street traffic in erection; it was very economical as compared with underground railways; it was pleasant to travel on; and it was comparatively free from risks of accident from collision; it was easy of access; the form of locomotive adopted was free from objection, as it was comparatively noiseless and did not appear to frighten horses when passing above them, and on the whole was more free from objection than any other form of road for rapid transit in towns.

Mr. G. Stephenson followed with a similar paper *On a New Safety Suspension Tramway or Light Railway*.

*The Importance of giving a Distinctive Character to the Needles Light*, by Sir Wm. Thomson, F.R.S.—He urged the necessity of giving a distinctive character to different classes of lighthouses, referring more particularly to the Needles light. He contended that the period of no revolving light ought to be more than half a minute, and stated that the three minutes revolving lights on the Irish coast had been done away with, and periods of a minute and half a minute substituted. To every fixed light a distinctive character should be given. Nine-tenths of our lighthouses had fixed lights, which had the advantage of being continuously visible, but lost the advantage of the great intensity of the revolving light. The distinctive character which he suggested should be given to the Needles and similar lighthouses was similar to the signals invented by Capt. Colomb, but instead of short and long flashes, he proposed to substitute short and long eclipses.

Sir Wm. Thomson read a paper *On an Improved Method of Recording the Depth in Flying Soundings, by substituting Chromate of Silver laid on by Albumen instead of Green Vitriol Solution.*

*On the Eddystone Lighthouse*, by J. N. Douglas.—He stated that the rock upon which this lighthouse was built had been so undermined by the sea that it had been determined to build another of larger dimensions at a distance of 120 feet from the present structure. He expressed a hope, however, that if Smeaton's wonderful handiwork were taken down, it would be considered worthy of an other site on English soil.

*On Recent Experiments in Telephones*, by Prof. Graham Bell, of Boston.—He stated at the outset that after the lecture delivered by Mr. Preece it would be scarcely necessary for him to put before them a description of the construction and the operation of the telephone in its present form, but he thought it would be interesting if he took up the subject in another light, and showed them the evolution of the telephone, and described to them the process by which the instrument had been brought up to its present state. Having alluded to the fact that it was now some years since his attention was first directed to the form of the vibrations of the air during the production of speech, and having pointed out that he was not aware how the idea of using electricity as a means of conveying these vibrations from one place to another suggested itself to him, Mr. Bell gave an interesting account of the time and labour which he, assisted by Dr. Clarence, J. Blake, Prof. Pearce, and other friends on the other side of the Atlantic, had devoted in endeavouring to discover some means by which the sound of the human voice could be successfully conveyed to whatever place was desired. He gradually traced the progress of these researches, and enumerated the different forms of instruments which had been invented for the purpose of accomplishing the object desired, several of which instruments he exhibited, at the same time explaining that experiments were still being made in Boston with a view to further improvements in, and in the further development of, the telephone. He confessed that he did not yet know which was the best form of instrument that could be used, reminded his audience that he did not bring the invention before them as a perfected one, that it was still in embryo, but expressed a hope that at the next meeting of the British Association he might have the opportunity of producing before them still more perfect forms of the instrument. Prof. Bell then announced that he had brought with him his telephonic organ, and that he should presently attempt to produce a little "bad" music for the benefit of the Association. This organ, he explained, resembled a harmonium or parlour organ. The reeds were all connected with a battery, and in front of each reed there was a little screw with a platinum point. When the instrument was blown the reeds vibrated against the screws, which were all connected with a telegraph wire, which had been brought into that room, and contact being made, the music was thus conveyed. He also explained that the organ was in the Guildhall, and that telegraphic communication had been made between that building and the Post-office, and between the latter place and the room in which they were then assembled. Experiments with the instrument were then proceeded with, the telegraph wire being attached by Mr. Preece to a telephone with a powerful battery and with a somewhat capacious "mouth." Harris, Mr. Preece's assistant, who was stationed at the Post-office, was then communicated with by that gentleman, and told to request the organist to "strike up," and almost immediately the audience were astounded by hearing with perfect distinctness the well-known air, "God save the Queen." The organist was then ordered, through Harris, to play "something with chords," and again the sounds of music were clearly heard, although this time the tune could not be recognised. Another instrument without a battery, was then connected with the wire, but as Mr. Bell had prophesied, the sounds of music conveyed to the audience by means of this instrument were very faint, being audible only to those at the top of the room. The first instrument was now again used, Harris being requested by the professor to sing as loudly as possible. In a second or two the favourite song "Auld Lang Syne" was heard with remarkable clearness, although many of the notes were somewhat "shaky." Harris next read a newspaper paragraph, and although the sound of his voice was distinctly heard, no one was able to ascertain the subject of what he was reading. Prof. Bell explained the reason of this, and informed the audience that the louder the voice was at the transmitting end the more indistinctly it was heard at the other end.

#### THE FRENCH ASSOCIATION AT HAVRE

THE French Association commenced its Session this year at Havre on August 23. M. Broca, the well-known anthropologist, is president this year, and after a few remarks on the rapid and steady progress of the Association, he announced as the subject of his presidential address, "The Fossil Human Races of Western Europe."

M. Broca spoke of the antiquity of historical nations, showing that it has been very much exaggerated, mainly by the nations themselves, and that even in the case of Egypt the historical epoch cannot be pushed back beyond 6,000 or 7,000 years. M. Broca then showed that up to a very late period man's advent on the earth was universally accepted as very recent, long posterior to the last geological phenomena which have modified the conditions of life and produced changes in climate, and with these in the flora and fauna. The president then gave a brief sketch of the change of opinion which has taken place during the past thirty or forty years, on the question of the antiquity of man; pointed out with what incredulity the accounts of the first finds of human remains under conditions showing their antiquity were received, and that it was only after long years of labour, 1840 to 1858, that Boucher de Perthes at last managed to obtain a serious hearing for the argument in favour of the genuineness of his discoveries and of the antiquity of man. The English palaeontologist, Falconer, went to Abbeville, in 1858, in order to examine at once the beds explored by Perthes, and the rich collection of cut-flints and bones which had been exhumed. M. Broca refers also to the early work in the same direction of Prestwich, Evans, Flower, and Lyell, stimulated by whose example, French men of science at last came forward in earnest to examine for themselves. The French Anthropological Society took the matter up, and the prudent and straightforward Isidore Geoffroy St. Hilaire at last declared that the last objections to the antiquity of man had vanished. Fossil man had proved his right to be received on the platform of positive science. The year 1859, which saw the doctrine of the antiquity of man make its way into science with irresistible force, was the beginning of one of the most fruitful of eras. New and boundless horizons were opened to the view of men of science; over all Europe geologists, archaeologists, anthropologists, set themselves to work with astonishing activity. Only eighteen years have passed since then, and never, perhaps, in any past time, have we seen so rich a harvest.

Boucher de Perthes raised only a corner of the veil which conceals early humanity. He proved that man lived during all the quaternary epoch, that he was the contemporary of the reindeer and other animals which have since migrated, of the mammoth, and other extinct animals. But was this all? and is humanity not older still? This latter question, still more grave than the former, was soon asked; more grave, for the duration of each of the three periods of the tertiary epoch was incomparably longer than the quaternary epoch. But M. Broca did not intend to discuss the researches concerning tertiary man; the discoveries made by M. Desnoyers at St. Prest, near Chartres, and by Prof. Capellini in several tertiary beds of Tuscany, tend to establish the existence of man during the pliocene period; those of the Abbé Bourgeois in the commune of Thenay (Loir-et-Cher) carry back even to the miocene, i.e., to the middle-tertiary, the existence of an intelligent being who knew how to cut flint, and who could be nothing else than man. But these facts, although collected by thoroughly competent observers, and although accepted after keen discussion by many eminent savants, are not yet sufficiently numerous nor incontestable to constitute a definitive proof. Tertiary man is not yet on the platform of science; he holds the place occupied by quaternary man twenty years ago. Will it be given to another Boucher de Perthes to demonstrate with irresistible evidence the existence of tertiary man? That is the secret of the future.

After referring to the vast amount of evidence for quaternary man obtained both in the Old and New World, M. Broca said that he is better known now than many peoples mentioned in history. We know enough to establish with certainty the multiplicity and the great diversity of quaternary races, and although the regions hitherto explored include only Western and a part of Central Europe, we can now, on this little corner of the globe, recognise and distinguish at least three fossil human races connected with two essentially different types. The two types are the dolichocephalic and the brachycephalic—the long-heads and the short or round-heads. Between these are the mesatocephalic.